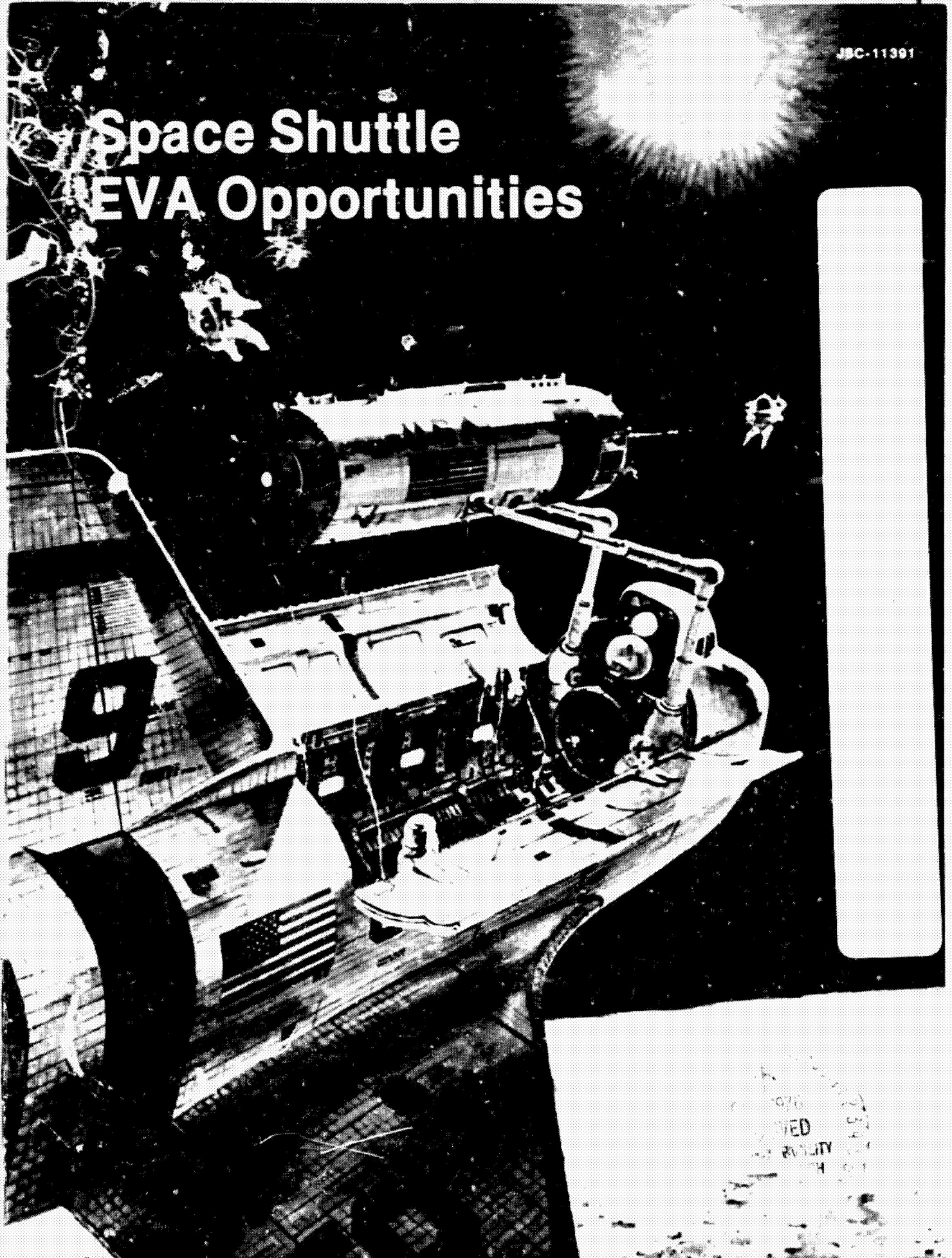


JSC-11391

Space Shuttle EVA Opportunities



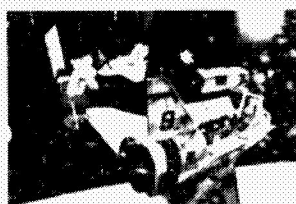
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"Man must rise above the earth — to the top of the atmosphere and beyond — for only thus will he fully understand the world in which he lives."

Socrates 500 B.C.

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS



COVER "Space Shuttles at Work"
From an original oil painting by Robert McCall. Artist McCall has long been an enthusiast of space exploration and renders here an imaginative glimpse into the future of the NASA Space Shuttle program and of the associated EVA opportunities available.

Foreword

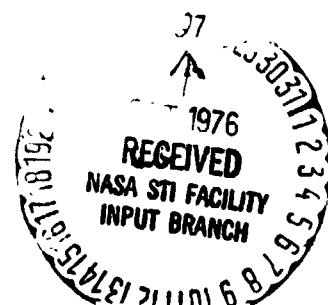
A unique role that man plays in the United States space program began when Astronaut Edward H. White II left the protective environment of his Gemini IV spacecraft cabin and ventured into deep space. His excursion — to perform a special set of procedures in a new and hostile environment — marked the start of the unique science of Extravehicular Activity (EVA).

Gemini missions proved EVA to be a viable technique for performing orbital mission operations outside the spacecraft crew compartment. Then, as Gemini evolved into Apollo, and Apollo into Skylab, EVA mission objectives pushed the science and art of EVA to their limit. New, more sophisticated concepts and methods were perfected, extending man's capability to obtain productive scientific return from the space environment. And, of course, Skylab demonstrated the application of EVA techniques to unscheduled maintenance and repair operations — salvaging the program and inspiring its participants to new heights of accomplishment. Because of this past success and usefulness, EVA capability has been baselined into the Space Shuttle program.

The National Aeronautics and Space Administration (NASA), in its Shuttle Orbiter program, is currently preparing to deliver to orbit payloads that may vary considerably in design and purpose. The payload may be a laboratory housing single biological cells or housing several scientist astronauts. It may be an entire astronomy observatory or a "small" component of a mammoth solar power station. EVA can provide sensible, reliable and cost-effective servicing operations for these payloads because EVA gives the payload designer the options of orbital equipment maintenance, repair and replacement without the need to return the payload to Earth or, in the worst case, to abandon it as useless space junk. Having EVA capability can help maximize the scientific return of each mission.

This brochure is meant to be a stimulus to the payload community by providing an insight into the opportunities of EVA sufficient to establish EVA as a primary design consideration.

▲ **ASTRONAUT EDWARD H. WHITE**
June 3, 1965 A.D.
Gemini — Titan 4





EVA Provisions

The term EVA, as applied to the Space Shuttle, includes all activities for which crewmembers don their space suits and life support systems and then exit the Orbiter cabin into deep space to perform operations internal or external to the Cargo Bay volume.

Further, EVA falls into three basic categories:

- **Planned** — EVA planned prior to launch in order to complete a mission objective
- **Unscheduled** — EVA not planned, but required to achieve payload operation success or advance overall mission accomplishments.
- **Contingency** — EVA required to effect the safe return of all crewmembers.

Each Orbiter mission will provide the equipment and consumables required for three two-man EVA operations, each lasting a maximum of 6 hours. Two of the EVAs will be available for payload operations and the third retained for Orbiter contingency EVA. Additional EVAs may be added with the additional consumables and equipment weights allotted to the appropriate payload. In providing this capability, the Shuttle program assumes all costs of the development and purchase of the Shuttle EVA systems provisions, EVA support equipment and EVA training of crewmembers. The costs attributable to payloads for any supplemental EVA capability will be quite nominal compared to those assumed by NASA for baseline equipment development and crew operational training.

Essential to EVA operations are the following Orbiter components and equipment:

Flight Deck — The Flight Deck is the upper cabin compartment, pressurized to sea level. It contains flight and payload systems controls, displays and monitoring devices as well as the Remote Manipulator System controls, displays and aft viewing windows. The aft windows enable all but 3 meters (10 ft) of the Cargo Bay adjacent to the cabin bulkhead to be seen, allowing out-the-window viewing of EVA operations.

Mid Deck — The Mid Deck is the lower cabin compartment, pressurized to sea level. It contains the crew living quarters and stowage volumes for cabin or EVA support equipment. The entrance to the Airlock and exit to the Cargo Bay are also located here.

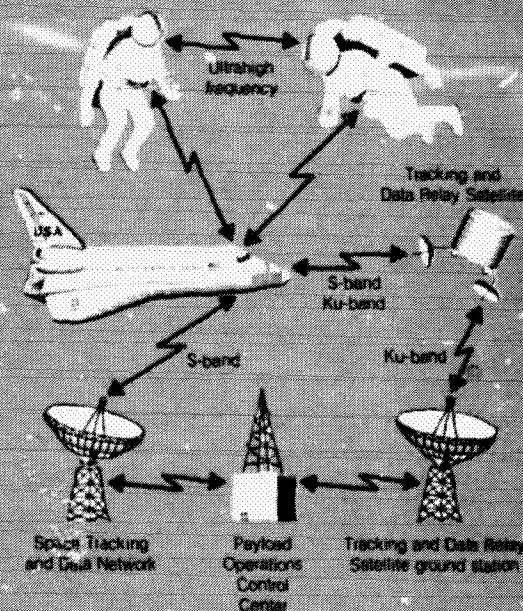
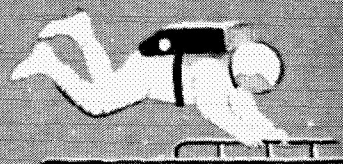
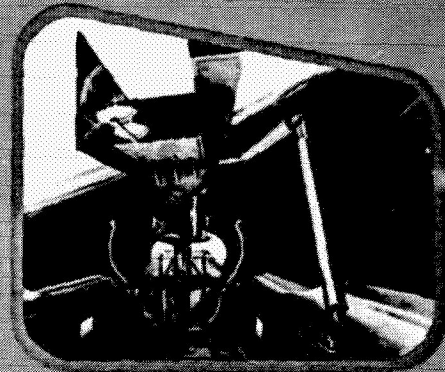
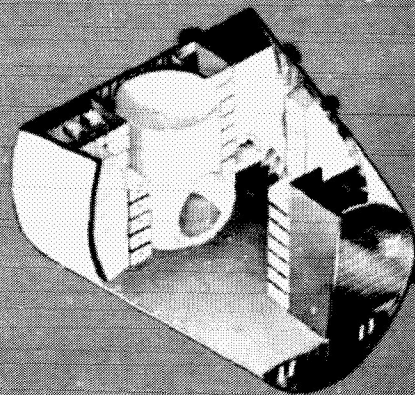
Airlock — The Airlock provides the means of transfer from the shirtsleeve environment of the cabin to the vacuum environment of space and contains the pressurization and depressurization systems necessary to effect such a transition. The Airlock is removable and can be installed in one of three different Orbiter locations, depending upon the payload carried. The baselined Airlock location is inside the Mid Deck compartment, allowing maximum use of Cargo Bay volume. However, it may also be rotated 180° and positioned in the Cargo Bay, still attached to the aft cabin bulkhead. For a habitable payload mission such as Spacelab, the Airlock may be positioned on top of a pressurized tunnel device which connects the cabin with the pressurized payload. The Airlock has two D-shaped hatches and provides a stowage volume for the crew Extravehicular Mobility Unit equipment when not in use.

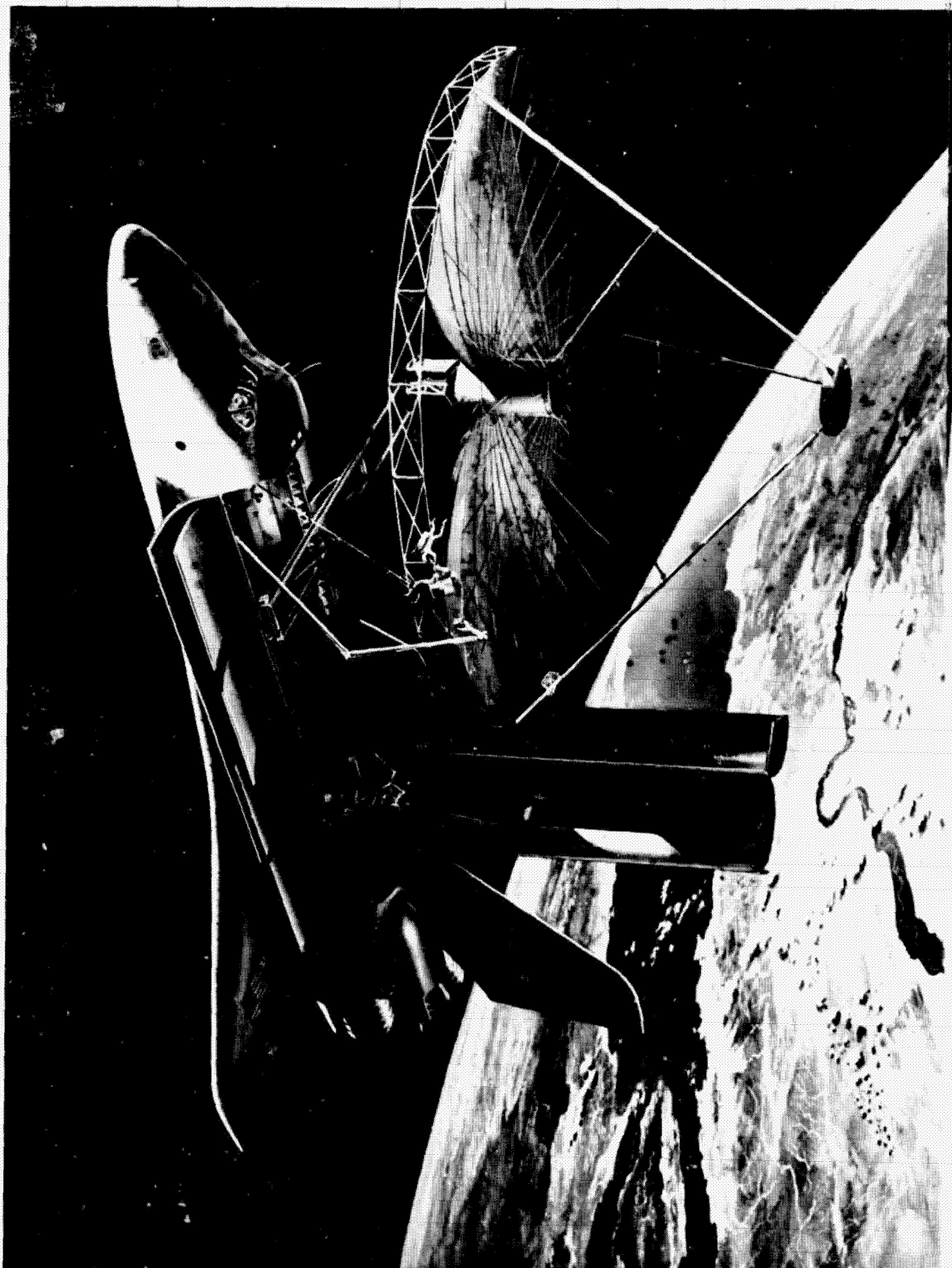
Cargo Bay — The Cargo Bay is the unpressurized mid part of the fuselage between the cabin aft bulkhead and the forward bulkhead of the empennage. The maximum usable payload envelope in the bay is 4.6 m (15 ft) in diameter by 18.3 m (60 ft) in length. The Cargo Bay doors extend the full length of the bay and are split along the centerline into two hinged sections. Adequate Cargo Bay lighting fixtures will be provided for payload external illumination.

Handrails and Handholds — Handrails and handholds, portable and fixed, are provided to facilitate zero-g crew movement within the Orbiter Flight and Mid Decks, in the Airlock and around the periphery of the Cargo Bay.

Extravehicular Mobility Unit — The Extravehicular Mobility Unit consists of a self-contained (no umbilicals) life support system and an anthropomorphic pressure garment with thermal and micrometeoroid protection. It provides a breathing environment at a pressure of 4 pounds per square inch absolute and incorporates provisions for internal liquid cooling, communications equipment, special EVA helmet visor protection, crew comfort devices and external restraint and tethering fittings. The unit and associated life-supporting consumables provide for a 6-hour nominal EVA with a subsequent recharge capability for additional EVAs.

Communications — The Orbiter provides ultrahigh frequency duplex communications from Flight Deck crewmembers to EVA crewmembers and between the latter. S-band and Ku-band channels will be used for "air-to-ground" communications between all Orbiter crewmembers and the appropriate ground control centers and for payload data transmission to ground. Both voice and data can be relayed to ground by the Tracking and Data Relay Satellite System, a network of advanced communications satellites that will replace many of the "handover" stations required during previous programs.





EVA Aids

To ensure maximum EVA capabilities, the following support equipment will be available for each Shuttle mission:

Remote Manipulator System

The Remote Manipulator System consists of a large external arm which, in conjunction with certain payload supporting equipment, is capable of deploying, retrieving and operating on payloads weighing as much as 65,000 lbs. The system is an electromechanical device, 15.2 meters (50 ft) long, having shoulder, elbow and wrist joints along with an end effector. The manipulator is controlled from the aft crew station on the Flight Deck through direct vision complemented by a closed circuit television system with cameras mounted on the manipulator arm and in the Cargo Bay. The Shuttle Orbiter has baselined one Remote Manipulator System mounted on the left side longeron of the Cargo Bay.

During non-EVA periods, the Remote Manipulator System can remove payloads from the Cargo Bay and deploy them in a stabilized condition by the use of special guideways and retention devices. Stabilized payloads can also be retrieved for return-to-Earth or on-orbit servicing. Unique payload servicing requirements, however, may require the addition of payload-provided, special purpose end effectors.

When used to assist the EVA crewmembers, the Remote Manipulator System may perform one or more of the following useful functions.

- It can effect multiple transfers of equipment between the EVA work area and the replacement equipment stowage area.
- Equipped with handrails, it can be used by the EVA crewmember as a translation path to remote areas on the payload or Orbiter that require servicing.
- The attached lights can be used to supply additional lighting at the work area, and the attached closed circuit TV camera can aid in payload inspection tasks and in task coordination with the other Orbiter crewmembers and with the ground.

Tools, Restraints, Ancillary Equipment

To perform equipment maintenance, repair and replacement, the EVA crewmember requires certain tools, tethers, restraints and portable workstations.

A standard off-the-shelf tool set will be available for use in supporting EVA payload operations. These tools will be kept in the NASA ground inventory and flown as required for each payload. Any payload-unique tools required will be furnished by the payload user. A primary design goal, however, will be to design the payload components to be cost effective by allowing standard NASA-supplied hand tools to be used for their servicing.

The portable workstation will be the crewmember's restraining platform while performing EVA tasks and will provide foot restraints, stowage for tools, tethers, a portable light and other ancillary equipment. The workstation may attach directly to the payload, to the Orbiter structure or even to the Remote Manipulator System in supporting various EVA tasks. Designers requiring EVA workstations for their payloads will either build their own workstations per NASA specifications, or make use of any existing portable workstation(s) that is part of the NASA Orbiter baseline support equipment inventory.

◀ **THE REMOTE MANIPULATOR SYSTEM is available to assist EVA crewmembers in the transport and positioning of large payload components during the orbital assembly process and provides a ready translation path between Orbiter and payload.**



Handrails, crew restraints and adequate lighting will be available to the EVA crew to traverse safely to and from the workstation and payload. However, crew mobility and restraint provisions designed onto or into the payload as well as any special external or internal payload lighting fixtures must be payload provided and self sufficient.

The payload designer is encouraged to purchase and use standard, NASA-specified "universal" or "multimission" EVA support hardware where possible in order to minimize EVA crew training, operational requirements and cost.

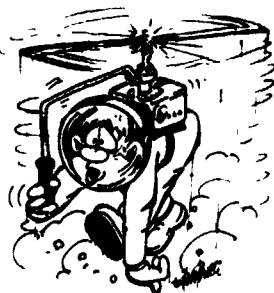
Manned Maneuvering Unit

With the Manned Maneuvering Unit, a propulsive backpack device, an EVA crewmember can reach areas beyond the Cargo Bay he could not reach otherwise. The unit, a modular device stowed in the Cargo Bay and readily attached to the Extravehicular Mobility Unit, can be donned, doffed and serviced by a single crewmember as needed during an EVA period.

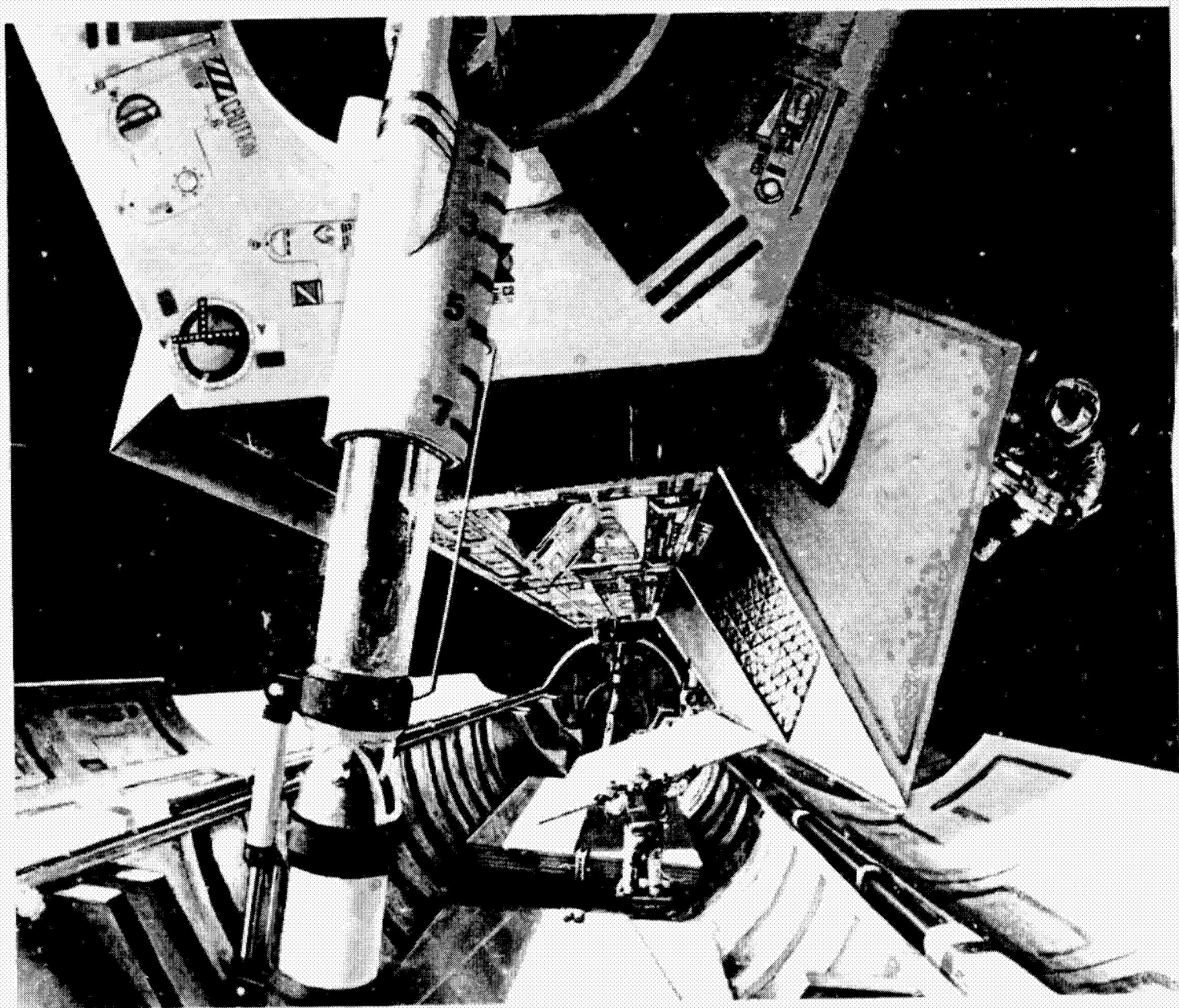
Since the Manned Maneuvering Unit has a six-degree-of-freedom control authority, an automatic attitude-hold capability and electrical outlets for such ancillary equipment as power tools, a portable light, cameras and instrument monitoring devices, the unit is quite versatile and adaptable to many payload task requirements.

Moreover, since the unit need not be secured to the Orbiter by tethers or other restraining devices, the crewmember can use it to "fly" unencumbered to berthed or free-flying spacecraft work areas, transport cargo of moderate size such as might be required for spacecraft servicing on orbit and retrieve small, free-flying payloads which may be sensitive to Orbiter thruster perturbation and contamination (the unit's own low-thrust, dry, cold gas nitrogen propellant causes minimal disturbance with no adverse contamination). In future applications, such as in-space assembly of large structures, the EVA crewmember can use the unit to easily position himself for supervising and inspecting automated techniques or manual assembly. When the Manned Maneuvering Unit is flown to support payloads, its weight and volume will be allotted to payloads.

◀ **MANNED MANEUVERING UNIT OPERATIONS** in the near vicinity of the Orbiter allow a close-up inspection of payload components which are beyond the envelope of the Cargo Bay and reach of the Remote Manipulator System.



EARLY MANNED MANEUVERING UNIT CONCEPTS



AN OUT-THE-WINDOW VIEW OF SHUTTLE ORBITER CARGO BAY EVA OPERATIONS. The EVA crew uses established operational capabilities, tested support equipment and validated procedural techniques in accomplishing payload mission objectives.

EVA Capabilities

Given adequate restraints, working volume and compatible man-machine interfaces, the EVA crewmembers can duplicate almost any task designed for manned operation on the ground.

The following typical EVA tasks demonstrate the range of EVA opportunities available to the payload designer:

- Inspection, photography and possible manual override of vehicle and payload systems, mechanisms and components
- Installation, removal or transfer of film cassettes, material samples, protective covers, instrumentation and launch or entry tie-downs
- Operation of equipment, including tools, cameras and cleaning devices
- Cleaning of optical surfaces
- Connection, disconnection and storage of fluid and electrical umbilicals
- Repair, replacement, calibration and inspection of modular equipment and instrumentation on the spacecraft or payloads
- Deployment, retraction and repositioning of antennas, booms and solar panels
- Attachment and release of crew and equipment restraints
- Performance of experiments
- Cargo transfer

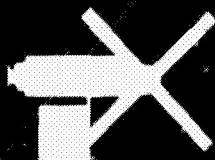
These EVA applications can demechanize the operational task and thereby reduce design complexity (automation), simplify testing and quality assurance programs, lower manufacturing costs and improve the probability of task success

Shuttle EVA Timeline

Mission activities (2 hrs)	EVA preparation (1.5 hrs)	EVA operations (6 hrs maximum)		Post EVA operations (1.5 hrs)
		Shuttle program provides	Payload options	
→ O ₂ prebreathing (3 hrs)		Two 6-hour (max), 1 or 2 man EVAs per flight	● Additional EVA consumables	
		● EVA crew training	● Flight specific EVA crew training	
		Remote Manipulator System EVA support	● Special Remote Manipulator System end effectors	
		Support equipment (tools, restraints, lights, TV, etc.)	● Special support equipment	
			● Manned Maneuvering Unit	

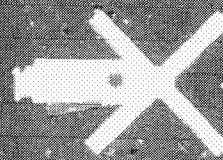
Skylab EVA

Mission Success



The Skylab EVA operations exemplify some of the possibilities for Shuttle payload EVAs. On Skylab, 6 EVAs consisting of 29 man-hours of outside-the-vehicle operations were planned to satisfy objectives for retrieval and replenishment of solar astronomy film data and particle sample collection devices. However, the loss of a meteoroid shield, the loss of one solar array panel and the jamming of the remaining array panel on the Orbital Workshop resulted in a total of 10 EVAs involving 82.5 man-hours. During the 10 EVAs, all planned prelaunch objectives were completed. Further, 13 **in-flight repair** tasks and 18 **additional mission objectives** were accomplished. As the adjacent tables illustrate, these EVA tasks varied in complexity as well as in their contribution to overall mission success.

Launch Contingency



SKYLAB EVA REPAIRS

Task Performed and Required Tools

- Rate gyro six-pack cable connection to the Apollo Telescope Mount computer interface panel - pliers
- Workshop solar panel release and deployment - cable cutter, vise grips, dental bone saw and prybar²
- "Twin-pole" sunshade deployment involving 24 1.5 m rods and a 7.4 m x 6.8 sunshade³
- Removal of 3 Apollo Telescope Mount aperture door latches (3 doors - 3 experiments) - box and wrench
- Pin open 3 Apollo Telescope Mount aperture doors (3 doors - 3 experiments)
- Cleaning of an optical decoupling disk - lens brush
- Release of a stuck electrical relay - ball-peen hammer
- Securing an antenna pivot axle following a pointing system failure - Skylab tool kit
- Manual rotation of a stuck spectrographic filter wheel - screwdriver¹

- ¹Had the rate gyro processor failed, mission termination would have been imminent.
- ²Had the solar panel failed to deploy, many mission objectives would have been lost.
- ³The workshop temperature soon dropped to an acceptable level for crew and equipment functioning.

EVA Ingenuity

ADDITIONAL SKYLAB EVA OBJECTIVES ACCOMPLISHED

Installation and Retrieval

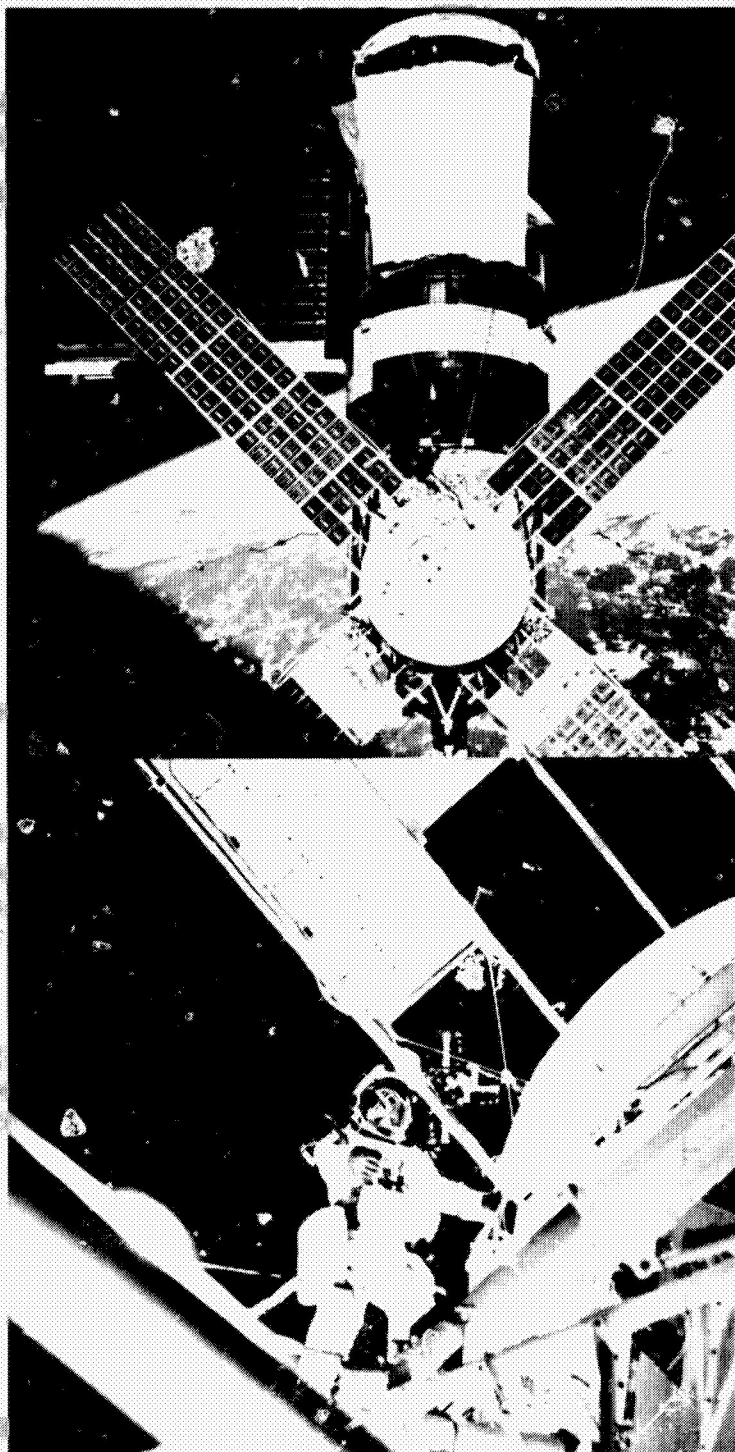
- Apollo Telescope Mount film packs
- "Sail" sunshade material sample
- Micrometeorite particle collection device
- Magnetospheric particle collection device
- "Parasol" sunshade material samples
- "Twin-pole" sunshade material samples
- Thermal control coating and shield material samples
- Cosmic ray experiment detector module

Retrieval Only

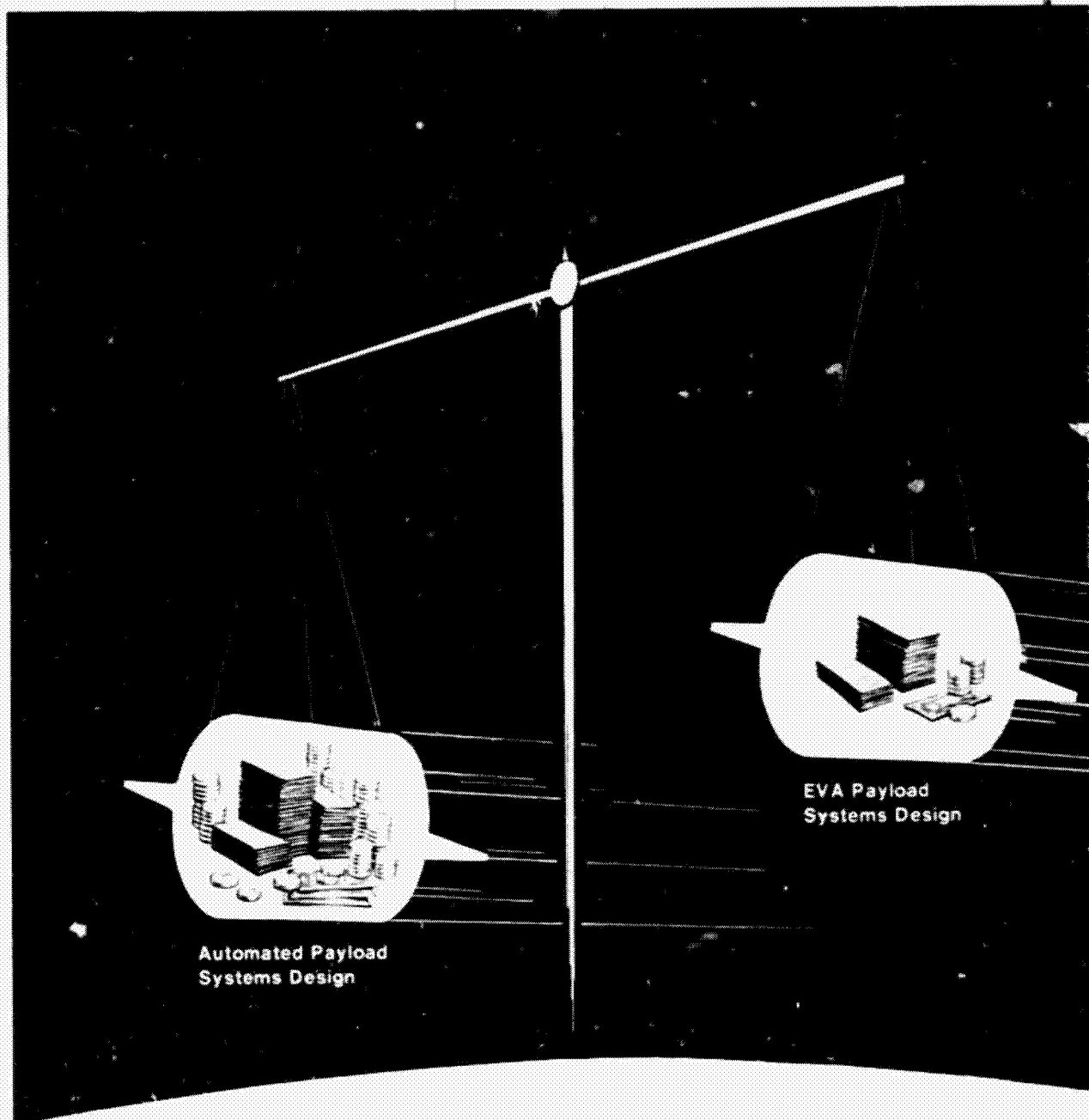
- Airlock module meteoroid cover sample
- Apollo Telescope Mount cover plate
- EVA communications cue card

Other

- Atmospheric experiment operations
- Comet Kohoutek contamination measurement and photographic documentation
- Comet Kohoutek far-ultraviolet photographic analysis
- 16mm motion picture photography
- 35mm still photography
- Extension of Apollo Telescope Mount center boom
- Panel temperature measurements using a digital thermometer

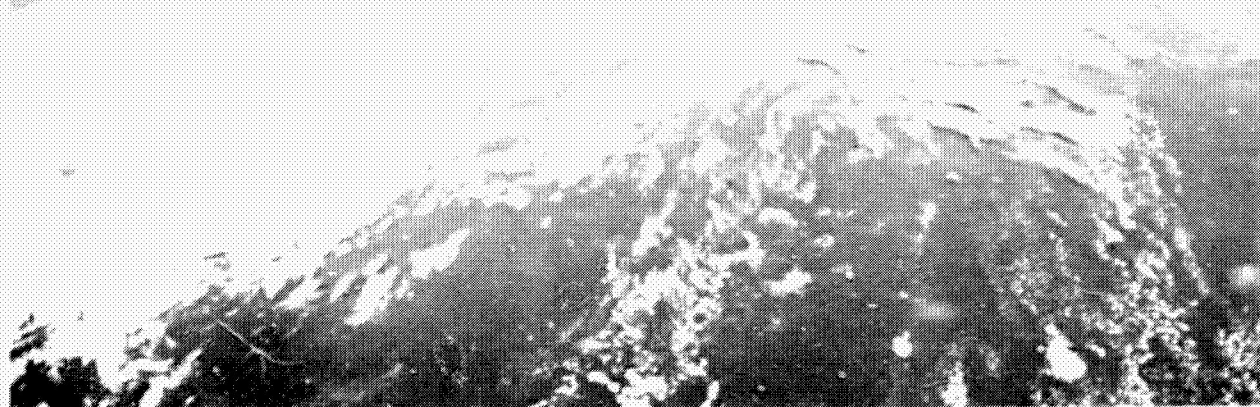


SCIENTIST - ASTRONAUT OWEN K. GARRIOTT, Skylab 3 science pilot, is seen performing EVA at the Apollo Telescope Mount of the Skylab space station cluster. Garriott had just deployed the Skylab Particle Collection Experiment on one of the Apollo Telescope Mount solar panels. Earlier during the same EVA, he had assisted in the deployment of the "twin-pole" sunshade.



Automated Payload
Systems Design

EVA Payload
Systems Design





EVA Cost Effectiveness

An analysis recently completed by NASA on Shuttle EVA opportunities established that cost-effective, programmatic benefits do result from the use of EVA in payload systems design. This study considered the following categories of EVA operations: planned routine, planned maintenance and unscheduled malfunction (remedial). Design and operations costs of a representative sampling of automated Shuttle baseline payloads were compared with the costs of the same payloads when designed for EVA operations. The EVA-oriented concepts developed in the study were derived from the baseline concepts and maintained mission and program objectives as well as basic configurations. The approach permitted isolation of cost saving factors associated specifically with incorporation of EVA into a variety of payload designs and operations.

The technique of feeding the EVA design data into a special design, development and production computer program and the extrapolation of this technique over the current Shuttle payload traffic model resulted in a net savings potential of millions of dollars for NASA and United States civilian payloads for planned routine EVA operations.

Further, designing planned maintenance EVA capability into the same representative payloads and then extrapolating over all payloads and users, resulted in additional multi-million dollar savings due to elimination of automated servicing equipment.

And last but far from least, the component malfunction potential for each of these representative payloads was analyzed and compared with projected Shuttle EVA remedial capabilities; through the same extrapolation process, this analysis, when applied over the entire payload spectrum, resulted in a further reaping of dollars saved through the use of unscheduled EVA.

These study results can only add credibility to a fact demonstrated empirically by NASA during previous space ventures: EVA properly designed into a payload system can contribute significantly to mission success — and save valuable science dollars for the user as well.



EVA Crew Training

Efficiency — The Name Of The Game

The Space Shuttle operational launch schedule will place new and arduous demands on the NASA crew training program. During each of the years 1965 and 1966, NASA launched five Gemini spacecraft. At the peak of the lunar surface exploration in 1969, there were four Saturn/Apollo launches. At the peak of the Space Shuttle operational program (1984-88), NASA anticipates launching as many as 60 flights a year. To support this flight schedule, NASA must be able to produce an Orbiter flight crew each week qualified for specific mission objectives. Obviously, this will require an efficient, well disciplined training program — one that allows a crewmember to accumulate a wide variety of initial skills and then apply them over a broad spectrum of Orbiter and payload system mission objectives.

Crewmember Responsibilities

Space Shuttle crewmembers will be trained to accept the following areas of responsibility for specific mission support.

- **Commander**—will be in command of the flight and be responsible for the overall Orbiter operations, personnel and vehicle safety.
- **Pilot** — will be second in command of the overall space vehicle operations and be equivalent to the Commander in proficiency. He will be the second crewmember for EVA operations.
- **Mission Specialist** — will be proficient in payload and experiment operations with a knowledge of Orbiter and payload systems. He will be the prime crewmember for EVA operations.
- **Payload Specialist** — will be proficient in the payload and experiment operations and be responsible for the attainment of their objectives.

Training Methodology

NASA's EVA crew training program will be categorized as follows:

- **Advanced training**—one-time-only training required to *develop initial* crewmember *expertise* in using the Shuttle Extravehicular Mobility Unit, the Orbiter EVA-related systems and the physical skills required to operate these systems.
- **Flight specific training** — training required to enable *accomplishment* of *specific* payload EVA operational *objectives*. This training takes place after the crewmember has been assigned to a specific flight.
- **Recurring training** —training for the crewmember who has previously flown a similar mission and required to *regain or maintain knowledge* of flight specific EVA systems, tasks and physical skills.

Development of required crewmember EVA skills in the "advanced" and "flight specific" training categories begins in the classroom. The classroom session may address such subjects as EVA operations and training philosophy, procedural techniques or payload system operations. Its goal is to achieve a level of knowledge that is prerequisite to learning operational skills.

EVA operational skills are developed and perfected in a variety of vehicular mockups and training facilities at the Johnson Space Center. Using these, the crew becomes familiar with the EVA working environment and is able to

develop payload operations techniques, efficient use of the EVA support equipment and crew procedures tasks required to do the payload EVA job. Training devices employed in this operational skill development may include the full-size Orbiter "one-g" mockup, the Orbiter underwater neutral buoyancy (zero-g) trainer, the altitude chamber, the Extravehicular Mobility Unit/Airlock trainer and the various Remote Manipulator System and Manned Maneuvering Unit part- and full-task simulators.

Supplier and User Training Responsibilities

To achieve flight crew readiness for any given payload EVA mission requires, from the conception of EVA requirements to the actual in-flight achievement of the payload objectives, a coordinated Shuttle program/payload user effort. To this end, the Shuttle program accepts the following responsibilities for crew training in EVA payload operations:

- To provide the training required to prepare a crewman to perform EVA in a deep space environment in support of planned, unscheduled or contingency payload operations.
- To provide the Orbiter one-g, neutral buoyancy, Extravehicular Mobility Unit/Airlock, Remote Manipulator System and Manned Maneuvering Unit trainers
- To provide a standard complement of basic Orbiter training hardware, i.e., handtools, tethers, workstations, foot restraints, handrails, etc.
- To provide the detailed crew procedures required to support each training exercise

In turn, the Shuttle program will require the payload user to accept the following responsibilities.

- To provide the initial set of payload system operating procedures to serve as the basis for detailed crew procedures development
- To provide payload-specific training articles that have a direct EVA interface. Depending upon the EVA task requirements, one-g and neutral buoyancy training articles could be required. The fidelity will be suitable to the task, more critical crew interface tasks will require higher fidelity training articles
- To provide *special* payload handling and support tools and equipment not in the standard NASA inventory
- To provide *special* Remote Manipulator System end effectors required for payload EVA support
- To provide payload requirements for a Manned Maneuvering Unit

Dollars and Sense

At this point the Shuttle "user" should recognize several potential monetary advantages of a payload system designed and built around established EVA operational guidelines. First, an EVA system can allow significant design simplifications saving dollars otherwise needed for automation. Consequently, specialized crew training in complex hardware is reduced, minimizing or eliminating "flight specific" training requirements. Also, as a result of their "advanced" training, which is free to the user, Orbiter crewmembers assigned to a specific payload mission will be able to accomplish many standardized EVA tasks. By using as many of these standardized EVA tasks as possible in the design of his system, the user can save additional training dollars.

A Payload EVA Mission Profile

Space Telescope



Program Features

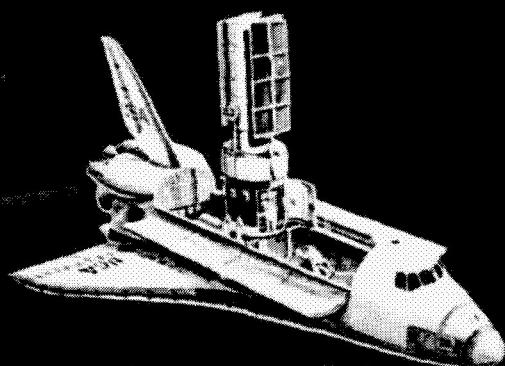
Even on the clearest of days and nights, the atmospheric envelope encasing the Earth significantly degrades astronomical observation. In attempts to gaze through it, the astronomer finds the sight distorted and blurred.

The Space Telescope, to be orbited in the early 1980's, will transport the astronomer's vision beyond the Earth's hazy shroud, establishing an orbital observatory position about 270 nautical miles above its surface.

From there, the telescope will be able to penetrate deep space, even to the outer fringes of the universe. Without the encumbrance of an atmospheric veil, astronomers will be able to do the following:

- Study two newly discovered very powerful and very controversial deep space radio energy sources — quasars and pulsars
- Locate and study black holes — collapsed former stars having extremely powerful gravitational fields
- Evaluate the process of star formation
- Monitor atmospheric and surface phenomena of the planets within our own solar system — including the Earth
- Provide new hypotheses on the origin and the destiny of the universe

A diffraction-limited telescope system with a 2.4 meter diameter primary mirror, the Space Telescope is comprised of three major assemblies: The Optical Telescope Assembly containing the aperture and lens mechanisms, the Scientific Instruments packages containing individual experiment electronics and optics and the Support System Module providing the attitude control and data-handling and transmission devices. Primary electrical power for the assemblies is provided by solar panels, complemented by batteries for dark-side Earth orbital operations. The Space Telescope is being designed for a 15-year operational lifetime, which will include periodic on-orbit servicing and maintenance through EVA and occasional retrieval and deorbit for ground refurbishment.



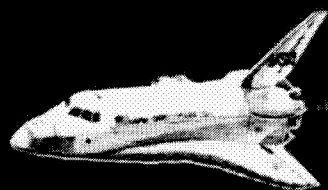
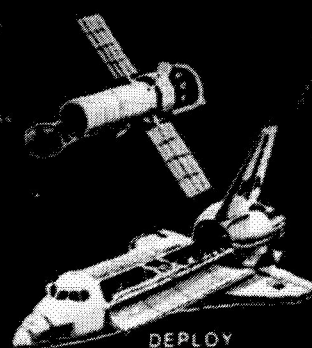
EVA SERVICING

PLANNED EVA CANDIDATE TASKS

- Inspect and photograph Space Telescope
- Scope potential maintenance tasks
- Prepare for on-orbit maintenance: unstow and assemble equipment transfer devices and open Space Telescope access doors
- Remove and replace Space Telescope equipment items:
 - Optical Telescope Assembly fine guidance and figure for us sensors
 - Optical Telescope Assembly electronics package
 - Scientific instruments modules
 - Various science instruments
 - Support System Module fixed star trackers and reference grids
 - Data management subsystem modules
 - Pointing control subsystem modules
 - Electrical power subsystem modules
 - Instrumentation and communication subsystem modules
- Secure spent modules, equipment transfer devices and Space Telescope access doors
- Deploy and retrieve payload experiments

UNSCHEDULED EVA CANDIDATE TASKS

- Inspect and photograph problem areas and verify repair or replacement plan
- Manually override solar array and high gain antenna unattach, reattach and deploy/retract mechanisms
- Replace actuators and repair mechanisms of fore and aft aperture door, solar array and antenna
- Replace and/or upgrade sensors, docking target and lights
- Unlatch, open, close and lock fore and aft aperture door
- Replace contamination seals and align all small, quakes, door hinges and actuator mechanisms
- Mate Remote Orbiter, Space Telescope interface umbilicals



DEORBIT AND LAND

EVA Mission Operations

EVA will be used for periodic replacement of life-limited or malfunctioning components and for updating of instrument packages to current state-of-the-art equipment with concurrent visual inspection of suspected problem areas.

A typical orbital servicing EVA mission would consist of the following segments:

- **Launch, rendezvous and capture** — The Shuttle Orbiter is launched from Kennedy Space Center, its orbit circularized, systems checked out, and an orbital adjustment made for rendezvous with the Space Telescope. Following rendezvous and a period of stationkeeping, the telescope is captured utilizing the Remote Manipulator System.
- **Berthing** — After capture and stabilization, the manipulator emplaces the telescope vertically in the Orbiter Cargo Bay. The telescope systems are then powered down in preparation for planned EVA maintenance operations.
- **Planned EVA maintenance** — After a required period of O_2 prebreathing (to guard against getting the "bends" during EVA while at a lower pressure), the Mission Specialist and pilot don their Extravehicular Mobility Units. They then enter, seal and depressurize the Airlock and exit into the Cargo Bay to begin the first of two 6-hour EVAs. In the vicinity of the Space Telescope, the crew configures the portable workstation and ancillary support equipment for the first module replacement task. Support System Module components and Scientific Instruments modules are removed from the Space Telescope; replacement items are then unstowed and inserted. The Payload Specialist monitors and coordinates these activities from the aft crew station on the Flight Deck using visual, TV and panel display aids. When EVA operations for the first day are completed, the crew restows the support equipment, returns to and enters the Airlock. The EVA terminates at Airlock repressurization. The second day's EVA activities will be similarly conducted.
- **Deployment** — After post-EVA telescope powerup and systems status verification are completed by the Payload Specialist in conjunction with the ground, the Space Telescope/Orbiter vehicle interfaces are released and the telescope is deployed by the Remote Manipulator System. A period of stationkeeping follows to assure proper telescope operation prior to final Orbiter departure.
- **Post-deployment operations** — Space Telescope servicing is complete, permitting the Orbiter to proceed to its next mission objective or to return to Earth.



Pursuit

Man has only begun to realize his achievement potential in meeting the scientific and environmental challenges above his planet. Extravehicular Activity has been shown to be one effective means of capitalizing on this potential. Other methods are available to meet experiment task objectives. Automated techniques and solo Remote Manipulator System utilization are viable means of meeting specific payload orbital operations requirements. But, as in the case of EVA, each method has its limitations, operational constraints and relative cost-effectiveness. The payload designer must be thoroughly familiarized with the various modes of task accomplishment in order to arrive at the best solution for application to the payload, one that is economical by design and reliable in operation.

Within the Johnson Space Center Crew Training and Procedures Division, the EVA Systems Section provides liaison with the payload community for experiment EVA operations development. Engineers in this section have multiprogram EVA experience which enables them to consult with interested payload principal investigators and designers and to assist them in determining the EVA potential for their payload and in optimizing its use.

In addition to providing EVA operations consultation, the EVA Systems Section publishes the JSC *Shuttle EVA Description and Design Criteria* document (ref. 1). The purpose of this document is to provide engineering personnel and payload principal investigators involved in EVA design, planning, operations and training with the definition of Orbiter EVA provisions, equipment and operations along with hardware design requirements and capabilities of the EVA crewmembers.

For Orbiter/payload interface information, the payload designer is further directed to the Johnson Space Center *Space Shuttle System Payload Accommodations* document (ref. 2) which describes the capabilities of the Space Shuttle System to accommodate payloads and defines the interfaces between the Space Shuttle System and the Shuttle payloads.

References

1. *Shuttle EVA Description and Design Criteria*, JSC 10615

2. *Space Shuttle System Payload Accommodations*
JSC 07700, Volume XIV.

Figure 1 - EVA growth within previous NASA manned space programs

